Analysis of Percutaneous Kyphoplasty under Different Types of Anesthesia for the Treatment of Multiple Osteoporotic Vertebral Fractures

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Abstract

Background Surgeons believe that the advantage of PKP under local anesthesia for the treatment of OVF in preventing interference with the general situation of elderly patients with multiple organ dysfunction. Surgeons can directly assess whether a spinal cord nerve injury occurs while the patient is awake. However, when patients with m-OVFs receive local anesthesia, fluoroscopy time often has to be increased,the operative time has to be extended, or the operation has to be terminated because of body posture-related discomfort, the toxic reaction of bone cement, and abrupt fluctuation of vital signs. No relevant study has thus far been conducted on the choice of the type of anesthesia to administer to patients undergoing PKP for m-OVFs.This study aimed to determine which of the two types of anesthesia is more suitable for PKP for m-OVFs.

Methods A retrospective study was conducted for 159 patients who underwent PKP for m-OVFs from January 2016 to January 2020; 81 patients underwent PKP under general anesthesia(Group G), and 78 patients underwent PKP under local anesthesia(Group L). Clinical and adverse events were compared between the two groups.

Results No difference in baseline information was found between the two groups. The intraoperative mean arterial pressure, average heart rate, average fluoroscopy times of each vertebral body, and operative time were less in Group G than in Group L. The VAS score was significantly lower than that before operation. The AVH, MVH, and the KA were significantly improved in both groups postoperation. The improvement in VAS score, AVH, MVH, and KA in Group G were higher than those in Group L. No significant difference in the incidence of complications was observed between the two groups.

Conclusion PKP under either general anesthesia or local anesthesia was reliable. Compared with PKP under local anesthesia, that under general anesthesia could more reliably maintain the stability of vital signs, alleviate preoperative pain in patients, and attain a better orthopedic effect. Moreover, the latter does not increase the complications of patients with m-OVFs. However, the high medical expense of PKP under general anesthesia is a factor to consider when choosing the type of anesthesia.

Background

Osteoporotic vertebral fractures(OVFs) often lead to pain, spinal deformity, and even the decline of the cardiopulmonary and digestive functions, significantly affecting the quality of life of the elderly[1–3]. Specifically, m-OVFs often render the elderly bedridden for a prolonged period, resulting in serious complications (e.g., pulmonary infection, pressure sores, and venous thrombosis) and posing a threat to the lives of patients[4–6]. Percutaneous kyphoplasty (PKP), one of the main treatments for OVF, can reconstruct spinal stability and restore vertebral height immediately[7–9]. Surgeons recognize the advantage of PKP under local anesthesia for the treatment of OVF in preventing interference with the general situation of elderly patients with multiple organ dysfunction. Surgeons can directly assess whether a spinal cord nerve injury occurs while the patient is awake. Moreover, patients who receive local

anesthesia do not need postoperative resuscitation and can get out of bed early, which is conducive to postoperative rehabilitation[10–12]. However, when patients with m-OVFs receive local anesthesia, fluoroscopy time often has to be increased, the operative time has to be extended, or the operation has to be terminated because of body posture-related discomfort, excessive local anesthetic drugs, the toxic reaction of bone cement, and abrupt fluctuation of vital signs. The literature shows that the type of anesthesia method does not affect the efficacy of PKP for a single OVF, and general anesthesia increases the incidence of complications and medical costs[10, 13–14]. No relevant study has thus far been conducted on the choice of the type of anesthesia to administer to patients undergoing PKP for m-OVFs. This study aimed to determine whether PKP for m-OVFs is more suitable under general or local anesthesia.

Methods

The study was authorized by the Ethics Committee of the Affiliated Hospital of Southwest Medical University.

Patient Population. All patients underwent PKP at the Department of Orthopedics of the Affiliated Hospital of Southwest Medical University from January 2016 to January 2020. All data were retrospectively reviewed based on medical records and billing statements. The inclusion criteria were as follows: (1) clinical manifestations of different degrees of waist and back pain, pain aggravated after turning over and getting up, no relief from conservative treatment over 2 weeks, and positive percussion pain of the corresponding spinous process; (2) no signs or symptoms of spinal cord or nerve root damage in the corresponding fracture segment before the operation; (3) presence of osteoporosis as determined by dual energy X-ray absorptiometry; (4) multiple vertebral body fractures on magnetic resonance imaging (MRI) with low signal intensity on T1-weighted imaging, high signal intensity on T2-weighted imaging, and high signal intensity on short TI inversion recovery; and (5) simultaneous PKP procedures on 3 or 4 vertebral bodies. The exclusion criteria were as follows: (1) coagulopathy in the patient or administration of anticoagulant therapy to the patient; (2) patients classified as Ⅲ or Ⅳ according to the American Society of anesthesiologists(ASA); (3) serious spinal instability caused by pedicle fracture; (4) symptomatic neurologic injury; (5) non-OVF conditions, such as tumors or infectious diseases, as confirmed by pathological examination; (6) Localized infection at the operative site and/or systemic sepsis; (7) unilateral puncture unable to achieve bone cement isocentric distribution and needs to supplement the contralateral puncture.

In accordance with the inclusion and exclusion criteria, 159 patients were recruited in this study, with 81 patients classified under Group G (general anesthesia group) and 71 patients in Group L (local anesthesia group). The baseline data of the patients were collected, including but not limited to age, gender, occupation, and bone mineral density. The volume of bone cement injected into each vertebral body and fracture was also collected.

Anesthesia and surgical procedures

Group G received general anesthesia via endotracheal intubation. General anesthesia was induced using etomidate 2 mg/kg, sufentanil 0.2 ug/kg, and cisatracurium 0.15 mg/kg during the operation. Moreover, 2–3% sevoflurane was inhaled continuously, and propofol 2 mg/(kg·h) was continuously pumped into the vein. The patients were then sent to postanesthesia care unit for observation after extubation. For group L, 1% lidocaine was used for local infiltration anesthesia. If the intraoperative systolic blood pressure was higher than 180 mmHg, nicardipine 0.03–0.3 mg/(kg·h) was continuously pumped to control blood pressure.

With fluoroscopy visualization, transpedicular (in the lumbar vertebrae) or extrapedicular (in the thoracic vertebrae) puncture was performed unilaterally. After reaching the posterior margin of the vertebral body, the bone needle was replaced with a working cannula. A balloon with a radiopaque media was inserted into the fractured vertebral body to restore the damaged vertebral body until adequate height restoration and kyphosis correction were obtained. The balloon was then deflated and withdrawn, and the resultant intravertebral cavity was filled with polymethylmethacrylate(PMMA) cement.

Outcome Measures

All patients underwent thoracolumbar anteroposterior and lateral plain film radiography, whole-spine MRI, and bone mineral density (dual energy X-ray absorptiometry) preoperatively. All patients underwent PKP and pathological biopsy simultaneously. The thoracolumbar plain films were routinely reviewed 1 d after the operation. The effects of the different types of anesthesia on the intraoperative conditions of the patients were evaluated by comparing the mean arterial pressure, average heart rate, blood loss, average fluoroscopy times of each vertebral body, and operative time (from the first vertebral puncture to the end of wound dressing) between the groups.

VAS scores (range: 0–10, with 0 indicating no pain and 10 indicating unbearable, severe pain) were recorded before the operation and postoperation. Following the method proposed by Lee and Kuklo[15–16], the measurement of the anterior vertebral height (AVH), middle vertebral height (MVH) and kyphotic angle (KA) was conducted before and postoperation. To evaluate the effects of the different types of anesthesia on clinical efficacy, the following were compared between the two groups: improvement in VAS scores {[(VAS score of pre-operation - VAS score of postoperation)]/VAS score pre-operationn}*100%, recovery rate of the AVH {(AVH of postoperation - AVH of pre-operation)/AVH of pre-operation}*100%, recovery rate of the MVH{(MVH of postoperation - MVH of pre-operation)/MVH of pre-operation}*100%, and the improvement rate of KA{(KA of pre-operation - KA of postoperation)/KA of pre-operation} * 100%. To evaluate the effects of the different types of anesthesia on postoperative recovery, the incidence of complications were also compared between the two groups. total expenditure and the expenditure for anesthesia, device, drug, and nursing were determined. Similarly, the expenses after the operation were calculated. All costs were expressed in dollars.

Statistical Analysis

All data were statistically analyzed using SPSS 19.0 (Chicago, IL, USA). The classified variable was calculated using a chi-squared test and Fisher's exact test. Continuous variables, presented as mean

standard deviation, were calculated using the Mann–Whitney test and paired or unpaired t-test with or without Welch's correction. All statistical data are presented in tabular form. P < 0.05 indicates that the difference is statistically significant.

Results

No difference in baseline information was found between the two groups(P > 0.05). The volume of bone cement injected into each vertebral body was larger in the Group G than in the Group L(P < 0.05). The intraoperative mean arterial pressure, average heart rate, average fluoroscopy times of each vertebral body, and operative time were significantly higher in Group L than Group G (P < 0.05), but no significant difference in intraoperative blood loss was found between the two groups (P > 0.05) (Table 1).

Table 1
Comparison of patients' characteristics

Characteristics	Group G (n = 81)	Group G (n = 78)	Test value	P value
Age	72.67±8.46	73.10±7.22	−0.349	0.728
Female	52(64.2)	51(65.4)	0.025	0.876
Occupation				
Worker	18	16		
Farmer	16	17		
Unemployed	8	7		
Technician	9	11		
Retiree	22	21		
Others	8	6	0.667	0.985
BMD	−3.61±0.80	−3.52±0.66	0.768	0.444
Fracture level				
$T_7 \sim T_{10}$	94	102		
$T_{11} \sim L_2$	118	114		
$L_3 \sim L_5$	72	65	4.557	0.919
Volume of bone Cement injected into each Vertebra(ml)	6.32±0.95	5.46±1.02	10.328	0.000
Mean arterial Pressure(mmHg)	101.1±7.49	134.2±12.95	−19.809	0.000
The average of heart beats	64.9±4.03	88.1±8.77	−21.495	0.000
Amount of Bleeding(ml)	67.2±22.37	69.6±21.41	−0.067	0.504
fluoroscopy times of each vertebra	18.7±1.70	24.4±1.81	−20.368	0.000
Time of operation(min)	79.6±14.37	94.5±13.82	−6.663	0.000
Complications				

Characteristics	Group G (n = 81)	Group G (n = 78)	Test value	P value
Bone cement	26(9.2)	18(6.4)	1.487	0.223
Neurological impairment	4(4.9)	2(2.6)	0.613	0.434
Vertebral infection	1(0.4)	1(0.4)	0.000	0.994
Cognitive dysfunction	7(8.6)	2(2.6)	2.732	0.098
Cardiopulmonary complications	4(4.9)	1(1.3)	1.733	0.188

The pain and VAS scores in the two groups were significantly reduced postoperation (P < 0.05). However, the improvement in the VAS score was significantly more favorable in Group G than in Group L (P < 0.05). The heights of the vertebral body in the two groups were significantly recovered postoperation (P < 0.05), but the recovery rate of the vertebral height in Group G was significantly preferable to that in Group L (P < 0.05). The KA in the two groups were significantly recovered postoperation (P < 0.05), but the improvement rate of the KA in the group G was significantly higher than that in the group L (P < 0.05) (Tables 2, 3).

Table 2
Comparison of VAS pain scores, AVH, MVH and KA of the vertebral body
before, postoperation in group G and group L

	Pre-operation	Post-operation	Test value	P value
VAS pain scores				
Group G	7.21±1.08	1.56±0.67	40.008	0.000
Group L	7.15±1.09	2.41±0.84	30.318	0.000
AVH(mm)				
Group G	18.31±2.75	22.69±2.98	−18.175	0.000
Group L	17.83±3.22	20.88±3.38	−10.948	0.000
MVH(mm)				
Group G	17.85±2.17	22.91±2.78	−24.189	0.000
Group L	17.69±2.50	20.83±5.58	−10.371	0.000
KA(°)				
Group G	19.78±2.67	14.29±2.89	23.523	0.000
Group L	19.25±3.27	15.56±3.42	9.249	0.000

Table 3

Comparison of the improvement rate of VAS pain scores, AVH, MVH, and KA of the vertebral body before, postoperation in group G and group L

	The improvement rate of VAS pain scores	The improvement rate of AVH	The improvement rate of MVH	The improvement rate of KA
Group G	77.8±10.57	24.5±6.60	28.5±6.34	28.2±9.11
Group L	65.2±14.49	17.6±4.52	18.1±4.27	20.2±7.54
Test value	6.282	14.356	17.715	9.013
P value	0.000	0.000	0.000	0.000

Bone cement leakage occurred in 26 cases and 18 cases, nerve injury in 4 cases and 2 cases, vertebral infection in 1 case, cognitive dysfunction in 7 cases and 2 cases, cardiopulmonary complications in 4 cases and 1 case, respectively. No significant difference in the incidence of complications was determined between the two groups (P > 0.05)(Table 1). Leakage of the T10 vertebral bone cement into the spinal canal, compressing the spinal cord, was observed in 1 of 6 patients with a spinal cord injury in Group G. The patient suffered from numbness, pain, and fatigue on both lower limbs after the operation. The nerve function was not recovered after emergency bone cement removal. Grade C under American Spinal Cord Injury Association(ASIA) was retained at discharge. The remaining 5 patients were complete recovered after conservative treatment. Two patients suffered from postoperative vertebral infection, which was treated with bone cement removal, debridement, bone graft fusion, and internal fixation. However, 1 of 2 patients died of a secondary infection after the operation. The patients who suffered from postoperative cognitive dysfunction and cardiopulmonary complications recovered and were discharged after conservative treatment. The average medical expenditure incurred in Group G was 7247.8±40.54 US$, and that in Group L was 6752.6±37.21 US$. Hospitalization cost was significantly higher in Group G than Group L (P < 0.05).

Discussion

To minimize the effect on the general situation of elderly patients, PKP under local anesthesia is an effective method for treating OVFs[10–12]. Liu et al. reported that local anesthesia for single vertebra PKP surgery can effectively relieve pain. Local anesthesia can provide the same clinical efficacy and spinal deformity correction as that of general anesthesia. Moreover, PKP surgery under local anesthesia can effectively reduce anesthesia-related complications such as cardiopulmonary system, allowing patients to get out of bed early and reduce hospitalization time and medical expenses[13]. Fang et al. indicated that the type of anesthesia administered does not affect the clinical efficacy of PKP[14]. However, previous literature mainly focused on PKP for OVF of a single vertebral body. With the increasing aging of the population, patients with m-OVFs are often encountered in the clinical setting.

These patients who are about to undergo PKP for multiple vertebral fractures often need to be in a prone position for an extended time. Patients often have to increase the number of fluoroscopy procedures, prolong the operative time, or even terminate the operation because of body position-related discomfort, overdose on a local anesthetic drug, bone cement toxicity, and violent fluctuation of vital signs. However, no reports exist on the choice of anesthesia in PKP for patients with m-OVFs. In this study, we compared the effects of general anesthesia and local anesthesia on PKP for m-OVFs with respect to intraoperative conditions, clinical efficacy, spinal deformity correction, and medical expenditure.

During surgery under general anesthesia, vital signs such as mean arterial pressure and heart rate can be maintained within a relatively stable range because of the continuous application of narcotic analgesics, narcotic sedatives, and muscle relaxants, combined with efficient respiratory ventilation management. Patients lose the perception of pain stimulation, and no significant fluctuation of blood pressure and heart rate due to insufficient local anesthesia occurs during the operation. Abrupt fluctuations of blood pressure and heart rate need to be avoided to reduce cardiovascular complications and acute cerebral infarction[17–19]. Relative to those under local anesthesia, the operative time and fluoroscopy exposure times are reduced under general anesthesia for multiple vertebral PKP mainly because the patient shows no frequent change in position due to body position-related discomfort nor stimulation of intraoperative pain. With a general muscle relaxant, the surgeon can more effectively and accurately operate on the patient. For multiple vertebral PKP under general or local anesthesia, postoperative pain can be significantly alleviated, and a satisfactory clinical effect can be achieved. However, this study found that the improvement rate of postoperative pain in the local anesthesia group was lower than that in the general anesthesia group, and this difference could be attributed to the following: (1) Local anesthesia for multiple vertebral PKP is often inadequate, causing patients to experience severe pain during the operation, which significantly reduces the patient subjective satisfaction; (2) Patients with m-OVFs often have a rib fracture, humerus fracture, or intertrochanteric fracture simultaneously. Being in a prone position for an extended duration leads to perceptible body position-related discomfort, leading to patient dissatisfaction with preoperative pain management; (3) During PKP under local anesthesia, patients experience high local muscle tension. If the puncture cannot be achieved at one time, the puncture point and puncture angle will be difficult to adjust. Repeatedly adjusting the puncture angle increases the damage to surrounding soft tissue and nerve injury. (4) Often, patients under local anesthesia for PKP do not need time to recover from anesthesia after the operation, and patients can prematurely leave the bed, which shortens the time of wound repair. This study found that the vertebral height and kyphosis in the two groups significantly improved after the operation; however, the improvement rates in the vertebral height and local kyphosis Cobb angle were significantly higher in the general anesthesia group than in the local anesthesia group. The reasons could be as follows: (1) Under general anesthesia, the muscles around the spine become relaxed, and muscle relaxants can significantly reduce muscle tension, which facilitates the recovery of fracture vertebral height and correction of kyphosis; (2) Under general anesthesia, the operation is not affected by frequent changes in body position, unpredictable severe pain, and abrupt fluctuation of vital signs. Focus on precise positioning, targeted puncture, balloon dilatation, and bone cement injection is enhanced, which is conducive to the recovery of the vertebral height and

kyphosis correction; (3) When taking general anesthesia, patients will not suffer from unbearable pain due to the sudden increase of pressure in the vertebral body during balloon dilatation, which is conducive to injecting larger volume of bone cement into each vertebral body and promoting the recovery of vertebral height.

In this study, the incidence of bone cement leakage, nerve complications, vertebral infection, cognitive dysfunction, and cardiopulmonary system complications is similar to those reported in the previous literature[20–22]. The incidence of bone cement leakage and nerve complications was higher in the general anesthesia group than in the local anesthesia group, but no significant difference between the two groups was indicated. In the previous literature, one of the advantages of PKP under local anesthesia is that it can interact with patients during the operation, which can effectively prevent neurological complications. However, the intraoperative interaction can only predict but not prevent the occurrence of spinal cord nerve injury. The surgeon should improve their surgical skills, optimize bone cement injection technology, and improve the accuracy of intraoperative C-arm fluoroscopy as the preferred choice to prevent bone cement leakage and spinal cord nerve injury. In this study, we used PKP under general anesthesia for m-OVFs. During the operation, the mean arterial pressure and heart rate were effectively maintained, and an effective lung ventilation control strategy was adopted. However, 7 patients still suffered from cognitive dysfunction even after the operation, which could be related to primary cardiovascular and cerebrovascular diseases in the elderly, organ dysfunction resulting in the slow metabolism of narcotic drugs, cerebral perfusion pressure, and intraoperative or postoperative hypoxemia. Although no significant difference was indicated between the two groups, cognitive dysfunction was still an important complication in elderly patients receiving surgery under general anesthesia. In addition, the incidence of postoperative cardiopulmonary complications in the general anesthesia group was lower than that in the local anesthesia group, which could be mainly caused by the short duration of general anesthesia and low dosage of narcotic drugs, allowing the patients to return to normal function early after the operation and recover their cardiopulmonary function. In this study, 2 patients suffered from postoperative vertebral infection, which was treated with bone cement removal, debridement, bone graft fusion, and internal fixation; 1 of the 2 patients died of infection secondary to operation. All patients included in this study were injected with bone cement via unilateral puncture balloon dilatation during the operation. Precise puncture positioning was performed before the operation, and the pressure for balloon expansion pressure was gradually increased. Each patient only needed a set of operation-related equipment, which substantially reduced the medical expenses of the patients. However, the medical costs incurred by the general anesthesia group was still $500 more than that incurred by the local anesthesia group, on the average. The difference in medical expenses was also one of the important indexes for the selection of the type of anesthesia.

This study has several limitations. First, this research is a single-center, small-sample retrospective study. Multiple-center prospective studies should be conducted to verify the conclusions drawn in this study. Second, methods for appraising clinical outcomes, such as cost-utility analysis, were not applied in this study.

Conclusion

When PKP for the treatment of multiple vertebral fracures is performed simultaneously, general anesthesia can better maintain the stability of vital signs, such as mean arterial pressure and heart rate, reduce the radiation exposure times of the patients and operators, and shorten the operative time. Regardless of the type of anesthesia, patients can obtain a satisfactory clinical effect without an increase in the incidence of complications. The pain improvement rate, vertebral height recovery, and kyphosis correction effect are better in the general anesthesia group than in the local anesthesia group. For elderly patients about to receive PKP under general anesthesia for multiple vertebral fractures, effective measures should be observed to prevent cognitive dysfunction. In addition, another factor consider when choosing the type of anesthesia is medical expenses.

Abbreviations

PKP, percutaneous kyphoplasty; m-OVFs, multiple osteoporotic vertebral fractures; VAS, visual analog scale; AVH, anterior vertebral height; MVH, middle vertebral height; KA, kyphotic angle; OVF, osteoporotic vertebral fractures; MRI, magnetic resonance imaging; ASIA, American Spinal Cord Injury Association.

Declarations

Ethical approval and consent to participate

The study protocol was approved by the Ethics Committee of the Affiliated Hospital of Southwest Medical University.All patients provided written informed consent prior to their inclusion in this study.

Consent for publication

Not applicable

Availability of data and materials

Data will be available upon request to the first author ZS.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

ZS and WQ conceived the original study and developed the protocol together with WS, Statistical advice was provided by XS and YJ. ZS wrote the manuscript. All authors read and approved the final manuscript.

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References

1. Cui L, Chen L, Xia W, et al. Vertebral fracture in postmenopausal Chinese women: a population-based study[J]. Osteoporosis Int. 2017;28(9):2583–90. doi:10.1007/s00198-017-4085-1.

2. Boonen S, Dejaeger E, Vanderschueren D, et al. Osteoporosis and osteoporotic fracture occurrence and prevention in the elderly: a geriatric perspective[J]. Best Pract Res Clin Endocrinol Metab. 2008;22(5):765–85. doi:10.1016/j.beem.2008.07.002.

3. Kim DH, Vaccaro AR. Osteoporotic compression fractures of the spine; current options and considerations for treatment[J]. Spine J. 2006;6(5):479–87. doi:10.1016/j.spinee.2006.04.013.

4. Prather H, Hunt D, Watson JO, et al. Conservative care for patients with osteoporotic vertebral compression fractures.[J]. Phys Med Rehabil Clin N Am. 2007;18(3):577–91. doi:10.1016/j.pmr.2007.05.008.

5. Nogués X, Martinez-Laguna D. Update on osteoporosis treatment[J]. Med Clin (Barc). 2018;150(12):479–86. doi:10.1016/j.medcli.2017.10.019.

6. Gehlbach SH, Burge RT, Puleo E, et al. Hospital care of osteoporosis-related vertebral fractures[J]. Osteoporos Int. 2003;14(1):53–60. doi:10.1007/s00198-002-1313-z.

7. Lieberman IH, Dudeney S, Reinhardt MK, et al. (2001) Initial outcome and efficacy of "kyphoplasty" in the treatment of painful osteoporotic vertebral compression fractures.[J].Spine (Phila Pa 1976) 26(14):1631-8.

8. Zhu RS, Kan SL, Ning GZ, et al. Which is the best treatment of osteoporotic vertebral compression fractures: balloon kyphoplasty, percutaneous vertebroplasty, or non-surgical treatment? A Bayesian network meta-analysis[J]. Osteoporosis Int. 2019;30(2):287–98. doi:10.1007/s00198-018-4804-2.

9. Phillips FM, Ho E, Campbell-Hupp M, et al. (2003) Early Radiographic and Clinical Results of Balloon Kyphoplasty for the Treatment of Osteoporotic Vertebral Compression Fractures[J]. Spine (Phila Pa 1976) 28(19):2260-5. doi: 1097/01.BRS.0000085092.84097.7B.

10. Ru XL, Jiang ZH, Song BS, et al. Treatment of senile osteoporotic vertebral compression fractures with percutaneous kyphoplasty under local anesthesia.[J]. Zhong guo Gu Shang. 2013;26(10):824–

8.

11. Liu L, CHeng S, Lu R, et al. (2016) Extrapedicular Infiltration Anesthesia as an Improved Method of Local Anesthesia for Unipedicular Percutaneous Vertebroplasty or Percutaneous Kyphoplasty[J].Biomed Res Int 2016; ID5086414, 4 Pages. doi: 10.1155/2016/5086414.

12. M.Luginbühl. (2008) Percutaneous vertebroplasty, kyphoplasty and lordoplasty: implications for the anesthesiologist[J].Curr Opin Anaesthesiol 21(4):504–13. doi: 10.1097/ACO.0b013e328303be62.

13. Liu J, Wang L, Chai M, et al. (2020) Analysis of Anesthesia Methods in Percutaneous Kyphoplasty for Treatment of Vertebral Compression Fractures[J]. J Healthc Eng 2020:3965961. doi: 10.1155/2020/3965961. eCollection 2020.

14. Fang XT, Yu F, Fu SL, et al. Clinical outcomes of percutaneous kyphoplasty under local anesthesia for osteoporotic vertebral compression fractures.[J]. Zhonghua Yi Xue Za Zhi. 2013;93(33):2654–8.

15. Lee ST, Chen JF. Closed reduction vertebroplasty for the treatment of osteoporotic vertebral compression fractures. Technical note. J Neurosurg. 2004;100(4 Suppl Spine):392–6. doi:10.3171/spi.2004.100.4.0392.

16. Kuklo TR, Polly DW, Owens BD, Zeidman SM, Chang AS, Klemme WR. Measurement of thoracic and lumbar fracture kyphosis: evaluation of intraobserver, interobserver, and technique variability. Spine (Phila Pa 1976). 2001;26(1):61–5. doi:10.1097/00007632-200101010-00012.

17. Staender SEA, Mahajan RP. Anesthesia and patient safety: have we reached our limits?[J]. Curr Opin Anaesthesiol. 2011;24(3):349–53. doi:10.1097/ACO.0b013e328344d90c.

18. Urman RD, Punwani N, Shapiro FE. Patient safety and office-based anesthesia. Curr Opin Anaesthesiol. 2012;25(6):648–53. doi:10.1097/ACO.0b013e3283593094.

19. Tosi F, Genovese O, Jovanovic T, Visocchi M. Management of Anaesthesia. Acta Neurochir Suppl. 2019;125:381–6. doi:10.1007/978-3-319-62515754.

20. Yeom JS, Kim WJ, Choy WS, Lee CK, Chang BS, Kang JW. Leakage of cement in percutaneous transpedicular vertebroplasty for painful osteoporotic compression fractures. J Bone Joint Surg Br. 2003;85(1):83–9. doi:10.1302/0301-620x.85b1.13026.

21. Harrington KD. Major neurological complications following percutaneous vertebroplasty with polymethylmethacrylate: a case report. J Bone Joint Surg Am. 2001;83(7):1070–3. doi:10.2106/00004623-200107000-00014.

22. Park JW, Park SM, Lee HJ, Lee CK, Chang BS, Kim H. Infection following percutaneous vertebral augmentation with polymethylmethacrylate. Arch Osteoporos. 2018;13(1):47. doi:10.1007/s11657-018-0468-y.